

Heart size in older people

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The transverse cardiac diameter, the transverse chest diameter, and the cardiothoracic ratio have been measured from chest x-rays in 446 persons from a random sample of 487 older people aged 62 to 90 years. Cardiac diameter and cardiothoracic ratio showed significant increases with increasing age while the chest diameter showed a significant decrease. Since the cardiothoracic ratio is therefore unreliable in estimating heart size, transverse cardiac diameter was used. This diameter was larger in the presence of higher diastolic blood pressures. After excluding persons with diastolic pressures greater than 100 mmHg, prediction equations were calculated for normal cardiac diameter using age and weight as the independent variables. The addition of height or chest diameter to the equations did not improve prediction.

The use of posteroanterior chest x-rays to estimate heart size is attractive because of its simplicity. The present paper describes measurements of the transverse cardiac diameter, the transverse chest diameter, and the cardiothoracic ratio in a study of older people, and examines their statistical relations and their suitability for measuring heart size.

Methods

The persons examined were 215 men and 272 women aged 62 to 90 years who formed a simple random sample of the 27,000 older people living in a defined area of Edinburgh. The method of sampling with a comparison of respondents and non-respondents has been fully described elsewhere (Milne, Maule, and Williamson, 1971). This group of people has been undergoing longitudinal study for the past 5 years. The first examination in 1968 to 1969 comprised a history of physical health using a structured questionnaire, clinical examination, and a number of additional examinations including chest x-ray. The results described in this paper are based on this first and therefore cross-sectional examination. A posteroanterior chest x-ray was taken, at a tube-film distance of 183 cm, at the height of a less than maximal inspiration. The transverse cardiac diameter and the transverse chest diameter were measured to the nearest millimetre on the film using a Harpenden anthropometer (Tanner and Whitehouse, 1957) with straight branches. This instrument is a sliding caliper fitted with a counter window from which the measurement in millimetres can be read directly. The branches are long enough to allow the transverse cardiac diameter to be measured in one single operation, without the more complex manoeuvres

needed with a ruler and set square (Cowan, 1959). The transverse chest diameter was measured from the internal surfaces of the ribs, superior to the costal attachment of the diaphragm, at the point where the chest width is greatest (Cowan, 1959). Measurements were not made on the films which were technically unsatisfactory as a result of the position of the subject, poor penetration, or exposure during the wrong phase of respiration. A few of the persons examined could not be x-rayed because of physical or mental disability. These exclusions reduced the films available for measurements to those from 191 men and 255 women. The cardiothoracic ratio was computed as $100 \times \text{transverse cardiac diameter} / \text{transverse chest diameter}$.

Additional measurements made were height to the nearest millimetre with the Harpenden stadiometer, weight in a minimum of underclothing, to the nearest 100 g with a lever balance, and blood pressure with the London School of Hygiene sphygmomanometer (Rose, Holland, and Crowley, 1964). Diastolic blood pressure was recorded at the point where muffling of the sounds began.

Rose's questionnaire (Rose, 1962; Rose and Blackburn, 1968) was administered to all subjects by one medically qualified observer (J.S.M.). A 12-lead electrocardiogram was recorded from each subject using a direct writing portable electrocardiograph. The tracings were coded, using the Minnesota code by two observers independently. When codings disagreed the observers discussed the tracings and supplied a coding agreed between them (Kitchin, Lowther, and Milne, 1973). The answers to the questions and the coded electrocardiograms allowed the grouping of subjects as having probable ischaemic heart disease, possible ischaemic heart disease, or no evidence of such disease (Reid *et al.*, 1966).

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Reliability

Reproducibility of the questionnaire was tested before the survey began (Milne, Hope, and Williamson, 1970). The reliability of height, chest diameter, and transverse cardiac diameter was assessed using analysis of variance techniques.

A sample of 10 people was measured by the same observer on two separate occasions. In studying chest and heart diameters x-ray films were exposed on each occasion. The analysis of variance demonstrated that there was no systematic variation from occasion to occasion for any variable. Further, if the residual variance, which represents random measurement error, is expressed as a percentage of the population variance plus the residual variance, then the figures for height, chest diameter, and cardiac diameter are 0.6, 0.7, and 12.0, respectively. The lesser reliability of cardiac diameter as a measurement may be associated with chance variation in the points on the cardiac cycle at which films taken on two occasions are exposed.

The reliability of diastolic blood pressure was tested by considering the differences between the observer's times and standard London School of Hygiene times in a series of 12 timed sets of Korotkow sounds (Rose, 1965). The mean of these differences did not differ significantly from zero.

Results

The distributions of the transverse cardiac diameter, transverse chest diameter, and the cardiothoracic ratio (CTR) are approximately Gaussian. The mean values, with standard deviations and the numbers from which these statistics were derived, are given for these three variables, in three age groups of men and women in Table 1. Chest and heart diameters are significantly larger in corresponding age groups of men compared with women while the reverse is true of the cardiothoracic ratio. In both sexes, there are age-related increases in the mean values of

TABLE 1 Mean values and standard deviations (SD) of chest diameter, cardiac diameter, and cardiothoracic ratio in older people

Age and sex	Chest diameter		Cardiac diameter		Cardio- thoracic ratio (%)		No.
	Mean	SD	Mean	SD	Mean	SD	
Men							
62-69	301.6	17.8	136.0	15.1	45.1	4.6	108
70-79	293.6	20.1	138.5	14.5	47.3	5.2	66
80-90	292.1	13.6	144.3	12.6	49.4	3.8	17
Women							
62-69	256.4	19.3	128.1	14.2	50.1	5.0	132
70-79	250.1	18.3	131.6	13.6	52.7	5.2	97
80-90	239.8	23.2	133.9	15.3	56.0	5.9	26

TABLE 2 Linear regressions of variables related to heart size on age, in older people

Age and sex	Dependent variable	Coefficient of regression on age	SE of regression coefficient	r	No.
Men 62-90	Cardiac diameter	0.4490	0.1643	0.19	191
	Chest diameter	-0.5240	0.2074	0.18	191
	Cardiothoracic ratio	0.2366	0.0533	0.31	191
Women 62-90	Cardiac diameter	0.3507	0.1435	0.15	255
	Chest diameter	-0.9229	0.1962	0.28	255
	Cardiothoracic ratio	0.3373	0.0526	0.37	255

TABLE 3 Cardiothoracic ratio in older people

Age and sex	Cardiothoracic ratio			χ^2
	< 50	≥ 50	% ≥ 50	
<i>Men</i>				
< 70	93	15	13.9	9.40**
≥ 70	56	27	32.5	
<i>Women</i>				
< 70	70	62	47.0	14.74**
≥ 70	36	87	70.7	

** $P < 0.01$.

cardiac diameter and cardiothoracic ratio, with a fall with age in the mean values of the chest diameter. The significance of these differences is confirmed by the coefficient of regression on age of these variables and the corresponding correlation coefficients which are given in Table 2. The effect of age on the cardiothoracic ratio is also given in Table 3 which shows in men and women above and below 70 years of age the numbers with a cardiothoracic ratio above or below 50 per cent.

The value of the cardiothoracic ratio as an estimate of heart size, which can be used to study the progress of patients in clinical work, depends on the transverse chest diameter being, in any one individual, a constant standard with which the transverse cardiac diameter can be compared. Data given in Tables 1 to 3 show a significant decline in transverse chest diameter as age increases. Admittedly the study is cross-sectional but it is unlikely that the age difference in chest diameter is entirely due to secular trend or selection by death. The age-related decrease in chest diameter suggests that the

increase in the cardiothoracic ratio with increasing age overestimates changes in heart size. Transverse cardiac diameter therefore seems to be a more appropriate measurement with which to study the normal limits of heart size in older people.

It might be expected that the transverse cardiac diameter would be larger in the presence of ischaemic heart disease or of hypertension. The mean values of the diameter were examined in persons with probable, possible, and no evidence of ischaemic heart disease (Reid *et al.*, 1966) and in persons with diastolic blood pressure above and below 100 mmHg. No significant difference emerged in respect of persons in the study with and without ischaemic heart disease, but the mean cardiac diameter was significantly larger with diastolic pressures of 100 mmHg and more. These persons with higher blood pressure were, therefore, excluded, leaving 188 men and 201 women on whom the description of the range of the cardiac diameter was based and in whom the regressions of cardiac diameter on age remained significant. In addition to age, transverse cardiac diameter has been described as varying with transverse chest diameter (Cowan, 1960) and with weight and height (Ungerleider and Gubner, 1942; Ueda, Russell, and Yano, 1958-60).

In the age group 62 to 69 years, the coefficient of regression of transverse cardiac diameter on age was not significant in either sex. This age group, in whom age effects were absent, was therefore used to study the relation of transverse cardiac diameter to weight, height, and transverse chest diameter. This was done by calculating the linear regression of cardiac diameter in men and in women aged 62 to 69 years on each of these variables singly in separate equations (Table 4). The coefficients of regression in this table are significant with the exception of those for height in women.

The relation of cardiac diameter, age, and these

TABLE 4 *Regressions of transverse cardiac diameter on weight, height, and transverse chest diameter in men and women aged 62 to 69 years, with diastolic BP < 100 mmHg*

Sex	Independent variable	Regression coefficient	SE of regression coefficient	r	No.
Men	Weight	0.8230	0.1065	0.62	96
	Height	0.0491	0.0251	0.20	96
	Chest diameter	0.3555	0.0787	0.42	96
Women	Weight	0.7476	0.0826	0.66	106
	Height	0.0303	0.0186	0.16	106
	Chest diameter	0.2967	0.0598	0.44	106

other variables was further examined by multiple regression in men and in women aged 62 to 90 years with transverse cardiac diameter as the dependent variable. The fit of the lines was not improved by adding height or transverse chest diameter to the regressions after age and weight. In the sample examined, age and weight explained as much of the variance of the transverse cardiac diameter as would all four variables.

For prediction of values in clinical work the linear regressions of the transverse cardiac diameter on weight in three age groups of men and women are shown in Table 5. In the Fig. are displayed, in the same age groups of men and women, the regression lines with 95 per cent confidence limits.

When the simple random sample used in this study was drawn, a further simple random sample of 64 men and women born in 1904 and 1905, i.e. 62 to 65 years of age in the period of study, was examined for another purpose which included chest x-ray. After the exclusion of subjects with diastolic blood pressures of 100 mmHg or more, there remained 25 men and 24 women. In these subjects the transverse cardiac diameter measured from chest films, was

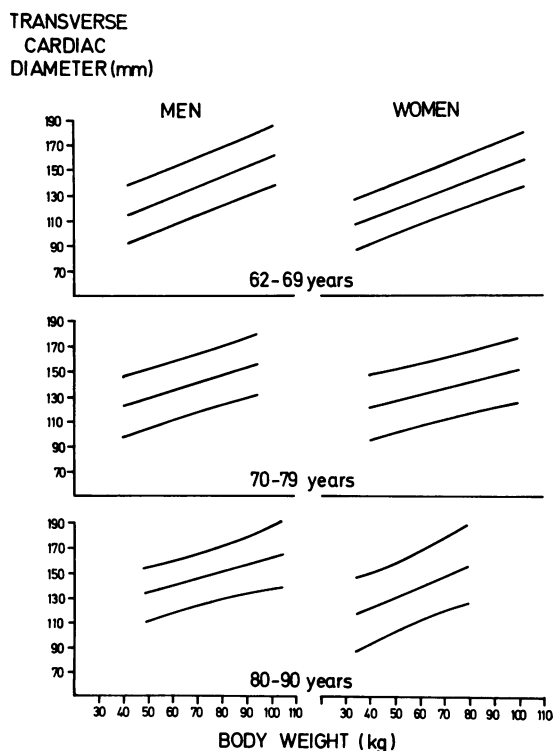


FIG. *Linear regressions with 95 per cent confidence limits to predict transverse cardiac diameter from age and weight in older men and women.*

TABLE 5 Regressions of transverse cardiac diameter on weight in 3 age groups of men and women (excluding those with diastolic BP ≥ 100 mmHg)

Sex and age	Constant	Regression coefficient	SE of regression coefficient	No.	r	Mean cardiac diameter (SD)	Mean weight (SD)	SE about regression
<i>Men</i>								
62-69	82.8218	0.7756	0.0899	108	0.64	136.7 (14.8)	69.5 (12.2)	11.41
70-79	97.0063	0.6238	0.1221	63	0.55	138.5 (13.6)	66.6 (12.0)	11.45
80-90	107.3236	0.5469	0.1796	17	0.62	144.1 (12.2)	67.2 (13.8)	9.90
<i>Women</i>								
62-69	80.3190	0.7511	0.0817	107	0.67	126.4 (13.5)	61.4 (12.0)	10.06
70-79	100.0138	0.5041	0.1141	76	0.46	131.4 (13.4)	62.2 (12.1)	11.99
80-90	88.1093	0.8469	0.2982	18	0.58	134.6 (14.7)	54.9 (10.1)	12.37

TABLE 6 Comparison of measured and predicted values of transverse cardiac diameter in a second random sample

Sex	Mean measured diameter \pm SE	Mean predicted diameter \pm SE	Mean difference between measured and predicted diameter	SE of mean difference	t	No.
Men	130.2 \pm 2.28	130.6 \pm 1.46	-0.4	1.76	0.23	25
Women	124.8 \pm 2.61	125.6 \pm 1.72	-0.8	2.11	0.39	24

compared with the diameter predicted from the regression equations given in this paper in Table 5. In both men and women, the mean difference between measured and predicted values of the transverse cardiac diameter did not differ significantly from zero (Table 6).

Discussion

The cardiothoracic ratio has been described as unsatisfactory by various authors. Ungerleider and Gubner (1942) refer to it as crude and inexact. Edge *et al.* (1964) conclude that the crude evaluation of cardiac enlargement in elderly people on the basis of a 50 per cent cardiothoracic ratio appears to be of no value. Since the ratio is still described in modern textbooks of radiology (Sutton and Grainger, 1969; Shanks and Kerley, 1962), it is worth restating that in older patients the cardiothoracic ratio is of little value as an indicator of cardiac enlargement. In the

present study a cardiothoracic ratio of 50 per cent and over was found in 71 per cent of women of over 70 years. This is comparable with 40 of the 53 women of 75 years and over described by Edge *et al.* Mayer, Blazsik, and Rappaport (1958) after describing narrowing of the lower chest cage in aged men and women say that 'by comparison the heart often appears enlarged'.

Edge *et al.* (1964) described a slight reduction with increasing age in the transverse chest diameter in men and a more striking fall in women. Cowan (1959) found a significant reduction with age in women only. The present study, based on a random sample of the population, shows significant age-related reductions in the chest diameter in both sexes, the reduction being greater in women. This age difference presumably cannot all result from secular trend towards larger chests or from the death of persons with wider chests. It seems likely,

particularly in older women, that developing kyphosis increases the anteroposterior chest diameter with resultant alteration in chest shape and narrowing of the transverse chest diameter. There is a significant negative relation between measurements of kyphosis and thoracic index, calculated as transverse divided by anteroposterior chest diameter (Milne, 1973).

Factors affecting the transverse cardiac diameter have been described by various authors. Ueda *et al.* studied citizens of Hiroshima in the ABCC Health Study (1958-60). They found that when the transverse cardiac diameter was examined in relation to weight, height, and age, it altered with alteration in any one of these variables, if the other two variables were specified. Their prediction equations therefore included age, weight, and height. Their subjects were aged 20 to 69 years. Cowan (1960), who studied elderly men and women from 60 to 79 years of age, found an increase in cardiac diameter with increasing age in men but not in women. In calculating prediction equations, he considered weight, chest diameter, height, and blood pressure as independent variables, but found that the addition of the latter two after weight and chest diameter did not improve prediction. These results differ from those in the present study in which the transverse cardiac diameter increases with age in both sexes. The present study revealed no improvement in prediction with the addition of height or chest diameter as independent variables after age and weight. The correlation between weight and transverse chest diameter is in fact greater than that between weight and height (Garn, 1962). In Cowan's (1960) equations, to predict cardiac diameter in women, allowance is made for age by computing the regressions separately in each decade. Ungerleider and Gubner (1942) found the influence of age and sex on heart size in adults to be relatively small compared with that of weight and height. They thought that age and sex could be disregarded in calculating prediction standards. These authors used insurance data based on younger subjects. The present study has shown that their findings are not true of older subjects, in whom a sex difference was present, and age and weight were the variables for prediction. Cowan (1960) also found a sex difference in the cardiac diameter of older people in his study.

The measurements described in this paper were made in the first round of a longitudinal study. It is hoped that eventually this study will allow the description of age changes in the same subjects instead of the age differences of cross-sectional study.

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